TITLE OF INVENTION:

SYNTHESIS, AND PHOTODYNAMIC THERAPY-MEDIATED ANTI-CANCER, AND OTHER USES OF CHORIN *E*6-TRANSFERRIN.

CROSS REFERENCE TO RELATED APPLICATIONS: None

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT: This invention was not directly supported by any federally sponsored research.

REFERENCE TO SEQUENCE LISTING, TABLES, OR COMPUTER PROGRAM LISTINGS: None

BACKGROUND OF THE INVENTION:

Rapidly growing cells require continuous intracellular iron transport in order to divide. Free iron, or iron salts, are absent in biological systems as iron salts can catalyze many un-favorable reactions (Conrad and Umbreit, 2000). Therefore, all iron delivery, storage, and transport in cells and higher organisms occurs while the iron is complexed to proteins. The major circulating iron transport protein is transferrin (Tf), which exists in blood at levels of 200 - 400 mg/100 ml (Ponka and Richardson, 1998). Each transferrin protein binds and transports two atoms of iron. To accomplish iron internalization, cells express transferrin receptors (TfR; Testa, et. al., 1993; Ponka, et. al., 1998; Ponka and

Lok, 1999) on their surface. These receptors interact with transferrin and two iron-saturated transferrins bind to one TfR. This TfR-Tf complex is internalized into the cell and the complexed iron is delivered to needed sites. Most tumor cells exhibit rapid growth rates and therefore internalize copious quantities of iron and express high levels of transferrin receptors (Gatter et. al., 1983; Niitsu et. al., 1987). Quiescent normal adult cells express little or no TfR (Gatter et. al., 1983; Tani et. al., 2000; Juhlin, 1989; Niitsu et. al., 1987) . Therefore, in many tissue areas, if a tumor exists, the only site of high TfR expression will be associated with the tumor cells. The expression of TfR in human tumor cells has been found to correlate with tumor grade, stage, progression, and metastasis. This has been seen in breast carcinomas (Wrba et. al., 1986), bladder transitional cell carcinomas (Seymour, et. al., 1987), and malignant melanoma (Van Muijen et. al., 1990). In addition, high levels of TfR have been observed in a metastatic lesion of a maxillary neoplasm, but not in the parental tumor (Yoda et. al., 1994),and the expression of TfR was higher in a human melanoma line selected for metastatic capability in nude mice than in the poorly metastatic tumor cells of the parental population (Van Muijen, et. al., 1991). In other studies, growth response to Tf was seen to correlate with metastatic progression in the B16 melanoma (Stackpole et. al., 1994) and Tf was identified as the major bone-marrow derived mitogen for bone-marrow metastasizing prostatic carcinoma cells (Rossi et. al., 1992). We have found that tumor cell expression of TfR can correlate with the metastatic ability of certain tumor cells (Cavanaugh and Nicolson, 1991, 1998; Cavanaugh et. al., 1999), which indicates that heightened TfR expression can be associated with the more aggressive tumor cell types.

Therapy against cancer is ideal when cancer cells are specifically killed while normal cells are left largely intact. Furthermore, an ideal treatment is achieved when cell killing occurs only at the site of the tumor and any non-specific killing at other sites is avoided entirely. To achieve these ends, researchers designing anti-cancer therapies will direct cancer cell killing agents at cell components which are novel to cancer cells or are present at much greater numbers on cancer cells than on normal cells. Various toxin-conjugated or radioactive antibodies directed towards antigens expressed only on the surface of cancer cells have been produced and tested (Hudson, 1999; Scott and Welt, 1997). Strategies to combat cancer using reagents directed at the transferrin/TfR system are currently being explored, and these are most successful when used to treat tumors of hematopoetic origin (Elliot et. al., 1988; Kemp et. al., 1992, 1995; Kovar et. al., 1995). The problem with any agent of this nature is that they can act, albeit to a lesser degree, on normal cells nearby and distant from the tumor site, causing side effects. To circumvent the latter problem, treatments have been devised which attack cancer only at the site of the tumor. If a pre-toxin could be specifically delivered to the TfR, and could furthermore be specifically activated to the toxin state at a certain site, then a tumor cell specific, site specific killing of tumor cells could be achieved. If at the same time, the pre-toxin remained non-toxic at other sites where the activation was not performed, then side effects could be avoided.

Photodynamic therapy (PDT) is an anti-cancer strategy that has been the subject of intensive study in recent years (Hsi et. al., 1999). The idea is to deliver to a tumor site a an inactive toxin which is then activated to a cell-killing toxin by exposure to light. Site-specific light irradiation causes site-specific cell killing. A number of different

compounds which become toxic when impinged upon by light have been developed (Hsi et. al., 1999). These compounds have been conjugated to various proteins (Akhlynina et. al., 1995; Donald et. al., 1991; Gijsens and De Witte, 2000; Del Governatore et. al., 2000) or covalently linked to other molecules (Katsumi et.al., 1994; Bachor et. al., 1991), to create a complex that when delivered *in vivo*, will produce a tumoricidal effect, when the tumor area is irradiated with light. One of the more useful PDT agents is chlorin *e*6, a nettle-derived porphyrin which is rendered toxic by irradiation with visible light.

We sought to conjugate transferrin with chlorin *e*6 , to develop an anti-cancer PDT agent which would exploit the high affinity of tumor cells for transferrin and the site-specific nature of PDT. Transferrin has been suggested as a delivery vehicle for anticancer drugs (Singh, 1999) and non-chlorin *e*6 PDT conjugates of transferrin have been produced (Hamblin and Newman, 1994). However, follow-up studies and extensive *in vitro* or *in vivo* work with the latter have been lacking.

The conjugation of chorin e6 to proteins usually occurs in solution with compounds such as EDC (1-Ethyl-3-[3-dimethylaminopropyl] carbodiimide hydrochloride) or cyclohexyl-3(2-morpholinoethyl) carbodiimide being present to activate chlorin e6 carbonyl groups to amine-reactive entities (Akhlynina et. al., 1995; Bachor et. al., 1991). With EDC, chorin e6 carboxyl groups form *0*-acylisourea intermediates for their conjugation to protein primary amines. Typically, once reactions are complete, conjugated proteins are separated from un-reacted intermediate and chlorin *e*6 by gel filtration. A number of these procedures were used to conjugate chorin *e*6 to transferrin with apparent success at conjugate formation, however the conjugate made using these methods consistently displayed none of transferrin's usual growth stimulating

activity on a particular target cell line. When conjugation using EDC was performed after immobilization of Tf to QAE-sepharose, biological activity of the ligand was maintained. The conjugated protein could be released from the gel by high salt only if a detergent such as CHAPS was present. Tf conjugated with chorin e6 in this fashion displayed cell growth-promoting activity, TfR binding activity, and displayed potent light-dependent killing of tumor cells in culture. As such, this patent and the invention is for this novel method for the conjugation of proteins to chorin *e*6, and for the subsequent use of this conjugate as a tumor-specific, tumor site-activatable, anti-cancer agent.

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BRIEF SUMMARY OF THE INVENTION:

Human iron-saturated transferrin was bound to quaternary-amino ethyl (QAE) sephadex in a buffer of 25 mM sodium phosphate, pH 7.2, containing 2 mM of the detergent CHAPS (PB/CHAPS buffer). The gel was washed free of unbound transferrin and was reacted directly with 1-Ethyl-3-[3-dimethylaminopropyl] carbodiimide hydrochloride (EDC) and the porphyrin chlorin e6, in the same buffer. Or, chorin e6 was reacted with EDC in a separate vessel, in the PB/CHAPS buffer, and unreacted chorin e6 removed from the mixture by adsorption to QAE-sephadex, all in PB/CHAPS. This latter soluble EDC-modified chlorin e6 was added to the immobilized transferrin to produce the immobilized conjugate. In either case, the transferrin was conjugated while bound to the gel and was washed free of un-reacted soluble conjugation components. The conjugate was then released from the gel by treatment with PB/CHAPS containing 0.5 M NaCl. The conjugate was dialyzed against PB for further use.

The conjugate was first shown to retain transferrin's growth promoting activity on the rat MTLn3 tumor line, in a low serum growth assay. The conjugate was then tested for its ability to compete with FITC-transferrin for binding to the transferrin receptor, using a western blot-mediated ligand binding assay. The conjugate was seen to possess an altered migratory pattern when analyzed by native gel electrophoresis. Finally, the conjugate was seen to kill tissue cultured tumor cells in a light-exposure dependent fashion. This killing effect was not evident in the absence of light or when excess un-conjugated transferrin was present, indicating a specific effect. Chlorin e6-transferrin prepared in this manner retains biological activity and is a candidate for use as a photodynamic therapy treatment of cancer and other disorders.

The invention presents a novel method for the conjugation of a porphyrin to a protein, in particular, the conjugation of chlorin e6 to transferrin. This results in the formation of a relatively tumor-specific ligand which possesses cell killing activity when activated by photodynamic therapy. Although the use of transferrin as an anti-tumor photodynamic therapy agent has been discussed by others, the use of chlorin e6, the use of this conjugation technique, and an illustration of putative effect as presented here is not evident in the scientific or patent literature.

BRIEF DESCRIPTION OF THE DRAWINGS:

Figure 1. A: Schematic of chorin e6. B: Schematic of the reaction of chlorin e6, EDC, and transferrin.

Figure 2. Effect of chorin e6 on the growth of Rat MTLn3 mammary adenocarcinoma cells. Cells were plated at 2,000 cells/well in 96 well plates in ∝MEM containing 5% FBS. One day after plating, media was changed to ∝MEM containing 0.3% FBS. Increasing levels of human holo-Tf (Native Tf) or human Ce6-Tf (both in PBS) were added to respective wells, in the amount indicated. Four days later, cells were quantitated using a crystal violet stain assay, where A590 correlates with cell number. **A:** an image of the crystal violet stained plate used in the assay is shown. **B:** A plot of the absorbances from A. Cell number and is seen to rise as the cells are exposed to increasing levels of native human Tf. A similar, albeit slightly lower rise was seen with Ce6-Tf, indicating intact biological activity in the latter.

Figure 3. Native gel electrophoretic analysis of Ce6-Tf. 10 μg quantities of all proteins listed were treated, loaded, and run out using the native gel system. The gel was fixed and stained with Coomassie blue. The results indicate a greater mobility of chlorin e6-transferrin (lanes 5 and 6) when compared to native transferrin (lane 4).

Figure 4. Competition of FITC-Tf binding to cell surfaces by Ce6-Tf. Transferrin solvent, human Ce6-Tf, or native human Tf were added to Rat MTLn3 mammary

adenocarcinoma cell monolayers equilibrated to 4° C. The final concentration of both transferrins was 1mg/ml. FITC- human Tf was then added to all wells at 100 µg/ml. After a 2h incubation, cells were washed, lysed, electrophoresed, blotted, and examined for FITC content by incubation with anti-FITC and an HRP-conjugated second antibody, followed by ECL. A strong band at 70,000 Kd was seen from cell lysates which received FITC-Tf only (lanes 4 and 5), indicating FITC-Tf binding to the cells. Both Ce6-Tf (lanes 6 and) and native Tf (lane 8) competed out the FITC-Tf as indicated by the absence of any FITC signal in lysates from cells treated with either. Lanes 1-3 were loaded with known amounts of pure FITC-Tf, for standardization. An image of the ECL X-ray film is shown. The results indicate functional binding of Ce6-Tf to the transferrin receptor.

Figure 5. Light-dependent killing of rat MTLn3 mammary adenocarcinoma cells by Ce6-Tf. This was a continuous exposure, serum-free assay performed using protocol A described in the cell killing section. Cells were plated in 24 well plates and grown to confluency in ∝MEM containing 5% v/v FBS. On day one, media was changed to ∝MEM only and increasing levels of Ce6-Tf were added to test wells to a final concentration from 1.25 to 5.0 µg/ml. Native Tf was added to control wells at 5.0 µg/ml. On days 2, 3, and 4, cells were exposed to light from an X-ray film box for 15 min. Media and all Tf was changed each day. On day five, all cells were quantitated using the crystal violet stain assay. Images of the stained plates are shown in **A.** Stained cell numbers were evaluated using a Bio-Rad Multi-imager. The results of image analysis are shown in **B**, where ODU/mm2 correlates with cell number. Results indicate a light-

dependent killing as plates kept in the dark during the process displayed no loss of cell numbers.

Figure 6. Light-dependent killing of MTLn3 and NRK cells by Ce6-Tf. This was a one-day exposure, serum-containing assay performed using protocol B described in the cell killing section. Cells were plated in 24 well plates and grown to confluency. On day one, media was changed and increasing levels of Ce6-Tf were added to test wells to a final concentration from 7.5 to 30 ug/ml. Native Tf was added to control wells at 30ug/ml. On day 2, media was changed to that without added Ce6-Tf or Tf. On days 2, 3, and 4, cells were exposed to light from an X-ray film box for 15 min. Media was changed each day. On day five, all cells were fixed, stained, and quantitated using the crystal violet stain assay. Stained cell numbers were evaluated using a Bio-Rad Multi-imager. Images of the stained plates are shown in **A** and **B.** The results of image analysis are shown in **C** and **D**, where ODU/mm2 correlates with cell number. Results indicate a light-dependent killing as plates maintained in the dark during the process displayed no loss of cell numbers. The MTLn3 cell line was more susceptible to the effects of the Ce6-Tf as it showed a decrease in cell numbers at the 15 ug/ml dose whereas the normal NRK line did not.

Figure 7. Light-dependent killing of Human MCF7 breast cancer cells by Ce6-Tf. This was a one-day exposure, serum-containing assay performed using protocol B described in the cell killing section. Cells were plated in 24 well plates and grown to confluency. On day one, media was changed and increasing levels of Ce6-Tf were added to test wells to a

final concentration from 7.5 to 30 ug/ml. Native Tf was added to control wells at 30ug/ml. On day 2, media in all wells was changed to that without added Ce6-Tf or Tf. On days 2, 3, and 4, cells were exposed to light from an X-ray film box for 15 min. Media was changed each day. On day five, all cells were fixed, stained, and quantitated using the crystal violet stain assay. Stained cell numbers were evaluated using a Bio-Rad Multi-imager. Images of the stained plates are shown in **A.** The results of image analysis are shown in **B**, where ODU/mm2 correlates with cell number. Results indicate a light-dependent killing as plates kept in the dark during the process displayed no loss of cell numbers. As with the rat lines studied previously, this human line was also shown to be susceptible to a combination of Ce6-Tf and light.

Figure 8. A: Effect of Ce6 alone on the viability of Rat MTLn3 cells. Cells were tested as per method B outlined in the cell killing procedure description. Confluent cells in ∝MEM containing 5% FBS were exposed to the indicated concentrations of Ce6, Ce6-Tf, or Tf alone. One day later, media was changed to that without added Ce6-Tf or Tf, and all cells were exposed to light for 15 min. This was repeated on days two and three. Cells were then fixed and stained with Coomassie blue. An image of the stained wells is shown. The results indicate that Ce6 alone had no cell killing effect. **B:** Effect of excess Tf on the killing effect of Ce6-Tf. Cells were set up similarly as above, except that treatments consisted of Ce6-Tf, or Ce6-Tf in conjunction with 500 or 1,000 µg/ml native Tf. Light exposure, media changes, and cell staining were carried out as in A. An image of the stained wells is shown. The results indicate that excess native Tf

diminished the killing effect of Ce6-Tf, indicating that the latter acts through a Tf-specific process.

DETAILED DESCRIPTION OF THE INVENTION:

Synthesis of chorin e6-transferrin: QAE sephadex A-50 (Sigma Chemical) was hydrated fully in water at a ratio of 1:100 (gel:water; w:v). The suspension was centrifuged at 1,000 X g for 5 min and the gel pellet equilibrated in 50 volumes of phosphate buffer (PB; 20 mM Na2HPO4, pH adjusted to 7.4 with KH2PO4). The gel was re-centrifuged and equilibrated in 10 volumes of phosphate buffer containing 2 mM CHAPS (3-[(3-cholidamidopropyl) dimethylammonio]-1-propane-sulfonate; buffer = PB/CHAPS). This was centrifuged at 1,000 X g for 5 min and the gel maintained in a minimal volume of PB/CHAPS. Iron-saturated human transferrin (Sigma Chemical) was dissolved in PB/CHAPS to a concentration of 10 mg/ml. To 2 ml of Tf solution was added 0.5 ml of equilibrated QAE-sephadex slurry. This was mixed slowly by rocking for 30 min. The gel was washed three times by suspension in and centrifugation from 25 ml PB/CHAPS. To ensure saturation of the gel, the transferrin binding process was repeated. To make the conjugate, to 0.5 ml of QAE-sephadex-Tf was added 0.5 ml of a 2 mg/ml chlorin *e*6 solution (Porphyrin products; Logan, Utah), dissolved in PB/CHAPS. To this was added 150 uL of 10 mg/ml EDC (1-Ethyl-3-[3-dimethylaminopropyl] carbodiimide hydrochloride; Pierce Chemical), dissolved in water. This mixture was rocked for 20 min at 25° C. The mixture was centrifuged at 1,000 X g for 5 min and the supernatant removed. To ensure complete conjugation, an additional 0.5 ml of chlorin *e*6 and 150 uL of EDC were added to the gel. The gel mixture was rocked again at 25° C for 25 min and the gel was washed four times by repeated suspension in and centrifugation (1,000 X g for 5 min) from 25 ml of PB/CHAPS. To elute the conjugated Tf, the gel was

suspended in 1ml PB/CHAPS containing 0.5 M NaCl. This was rocked for 20 min at 25° C, centrifuged at 1,000 X g for 5 min, and the supernatant collected. The elution step was repeated on the gel pellet and the supernatants pooled. The pooled chlorin e6-transferrin was dialyzed overnight at 4° C against 4L of PB containing 0.15 M NaCl.

Additional procedure for the removal of free chlorin e6: The pooled chlorin e6-transferrin (Ce6Tf) is dialyzed at 4° C against 25 mM sodium acetate, pH 4.8. To eliminate remaining un-conjugated chlorin e6, the dialysate is combined with 2 ml of packed SP-sepharose, previously equilibrated in the same buffer. This is mixed for 30 min at 25° C and the gel is washed three times by centrifugation from and re-suspension in 20 ml equilibration buffer. The bound chlorin e6-transferrin is released from the gel with 25 mM sodium phosphate, pH 7.2 ,containing 1.0 M NaCl. The released material is combined with 1/100 volume of 1% (w/v) ferric ammonium citrate, and dialyzed against 25 mM NaH2PO4, pH 7.2. With this procedure, transferrin possesses a net positive charge at a pH of 4.8, whereas un-modified (free) chlorin e6 retains a net negative charge. Therefore,the transferrin will bind to a negatively charged matrix, and the free chlorin e6 will not. This allows for the removal of free chlorin e6 via the washing procedure.

Additional procedure for the preliminary preparation of EDC-chorin e6: Chlorin e6 is dissolved at 1 mg/ml in 25 mM sodium phosphate, pH 7.2 containing 2 mM CHAPS. One tenth volume of 10 mg/ml EDC (in water) is added and allowed to react with the chlorin e6 at room temperature for 20 minutes. This is combined with an equal volume

of a 50% (vol/vol) slurry of QAE-sepharose suspended in and equilibrated in 25 mM sodium phosphate, pH 7.5, containing 2 mM CHAPS. The gel-reacted chlorin e6 mixture is allowed to react at room temperature for 20 minutes. The mixture is centrifuged at 1000 X g for 10 minutes and the modified chlorin e6 in the resulting supernatant is removed and added to QAE-sepharose immobilized transferrin for production of the conjugate as stated above. With this procedure, non EDC-reacted chlorin e6 will retain a net negative charge and will bind to the QAE-sepharose. Chlorin e6 which has reacted with the EDC at two or more carboxyls will possess a net positive charge and will not bind to the QAE-sepharose. Therefore, only modified chlorin e6 will be added to the protein and non-specific adherence of chlorin e6 to the QAE-sepharose-transferrin will be avoided.

Native gel analysis of chorin e6-transferrin: The acrylamide gel solution consisted of 0.37 M Tris, 0.17 M HCl, 9.75 % w/v acrylamide, 0.25 % w/v Bis-acrylamide, 2 mM CHAPS, 0.01% v/v TEMED and 0.025% w/v ammonium persulfate. This was poured into a 15 X 15 X 0.1 cm chamber and polymerized. Samples were treated by addition of one third volume of 1.48 M Tris, 0.68 M HCl, 8mM CHAPS, 0.01 % w/v bromophenol blue, and 20% v/v glycerol. Samples were loaded onto the acrylamide gel and the gel was placed into an electrophoresis chamber containing an anolyte of 20.16 M Tris, 0.01 N HCl. A catholyte of 0.02 M glycine and 0.01 N KOH was overlaid onto the gel and the samples were electrophoresed at 40 mA constant current until the dye front was 1 cm from the bottom of the gel. The gel was fixed in 40 methanol, 10% acetic acid and was

stained in fixative containing 0.2% Coomassie blue R250. The gel was destained with fixative.

Competition binding: This measures the ability of a material to inhibit the binding of FITC-transferrin to cell surfaces. FITC-Tf bound to the cells is detected by Western blotting of cell lysates and specific antibody-based detection of FITC in those. Rat MTLn3 mammary adenocarcinoma cells were grown to confluence in 12 well plates using media consisting of ∝MEM containing 5% v/v fetal bovine serum (FBS). Media was changed to ∝MEM only for 2 h an then again for overnight. The cells were equilibrated to 4° C, wells were drained and 1 ml of a binding buffer consisting of ∝MEM containing 25 mM HEPES (pH 7.5) and 3 mg/ml liquid gelatin was added to all wells. C*e*6-TF to be tested was added to respective wells to a concentration of 1mg/ml. Native human transferrin, as a known control inhibitor, was added to positive control wells to a concentration of 1 mg/ml. Negative control wells received transferrin buffer only. FITC-Tf was added to control and test wells to a concentration of 100 ug/ml. Cells were incubated at 4° C for 2h. All wells were washed 4 times with 2 ml PBS and cells were lysed with 0.5 ml PBS containing 2% Triton X-100, 0.1 U/ml aprotinin, and 100 μg/ml PMSF. Lysate protein was determined using the BCA assay (Pierce Chemical). Equal protein amounts of cell lysates were treated with SDS-PAGE treatment solution, were separated by SDS-PAGE, and blotted onto nitrocellulose. The blot was blocked and FITC-TF was detected by treatment with rabbit anti-FITC then with anti-rabbit IgG-HRP followed by ECL using an HRP substrate.

Growth assays: Rat MTLn3 mammary adenocarcinoma cells were plated at 2,000 cells/well in 96 well plates in ∝MEM containing 5% FBS. One day after plating, media was changed to ∝MEM containing 0.3% FBS. Increasing levels of human holo-Tf or human Ce6-Tf (both in PBS) were added to respective wells. Four days later, cells were quantitated using a crystal violet stain assay.

Cell killing assays: **A:** Serum-free media assays. These were performed to initially assess the effect of C*e*6-Tf and to verify its light-dependent killing. Target cells were grown to confluence in 24 well plates. On the day of the assay, media in all wells was replaced with 1 ml of fresh serum-free media and increasing levels of C*e*6-Tf added to test wells. Native human holo-Tf was added, at the highest Ce6-Tf dose, to control wells.

B: Serum-containing, one day exposure assays. For these, serum was maintained, to emulate *in vivo* conditions where excess endogenous normal transferrin would be present. In addition, the Ce6-Tf exposure was limited to 1 day to emulate a one time Ce6-Tf injection. Target cells were grown to confluence in 24 well plates. On the day of the assay, media in all wells was replaced with 1 ml of fresh serum-containing media and increasing levels of C*e*6-Tf added to test wells. Native human holo-Tf was added, at the highest Ce6-Tf dose, to control wells. One day after Tf addition, media in all plates was changed to normal culture media (without Ce6Tf).

With both assay methods, two plates for each line to be tested were plated and treated identically. One day after Ce6-Tf addition, test plates were exposed to the light

from an X-ray film box for 15 min. : the box was placed horizontally and the culture plates placed directly on the cover glass. The parallel plate from a given line was kept in the dark. The light treatment was repeated for 3 days. Media was changed (with [A] or without [B] added Ce6-Tf) each day, to maintain cell viability. On the fourth day, the cells were quantitated using a crystal violet stain assay: wells were drained and washed 4 times with 2 ml PBS; cells were fixed with 1 ml 5% v/v glutaraldehyde (in PBS) at 25° C for 20 min.; wells were washed 4 times with 2 ml distilled water and stained with 1 ml of a 1:1 (v:v) mixture of 0.2% (w/v) crystal violet and 100 mM CAPS (pH 9.0). Wells were drained and washed 4 times with 2 ml distilled water. After drying, cell density was determined using a Bio-Rad Multiimager, where ODU/mm2 correlates with cell number.

Transferrin competition of cell killing: These were performed to ensure that Ce6-Tf's cell killing effect was due to the function of the transferrin ligand: that the light-induced killing effect could be neutralized with excess native Tf. Method B. from above was used. Confluent cultures of MTLn3 cells in 24 well plates were treated with 30 ug/ml of Ce6Tf. At the time of Ce6Tf addition, certain wells also received human holo-transferrin so that the final concentration was 0.5 or 1.0 mg/ml. One day later, media was changed to normal culture media. Light-induced killing assays were continued and cells quantitated as stated above in method B.

Effect of Ce6 alone: To determine if Ce6 alone, if added in appropriate concentrations, would induce cell death. Gel filtration analysis indicated no significant change in Tf's molecular weight after Ce6 conjugation (data not shown). It was assumed from this that

less than 10 molecules of Ce6 were conjugated to each Tf protein. Ce6Tf was very active in causing light-induced cell death when initially present at 0.43 uM (30ug/ml), so free Ce6 was added to cultures at 4.3 uM, a ten fold molar excess, to ensure that Ce6 was present in greater amounts than that encountered by cells when exposed to Ce6Tf. So Ce6 was added to a final concentration of 2.5 μg/ml to confluent MTLn3 cells. Light-induced killing assays were conducted as stated in method B above.